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# ZIGBEE EXPLOITED

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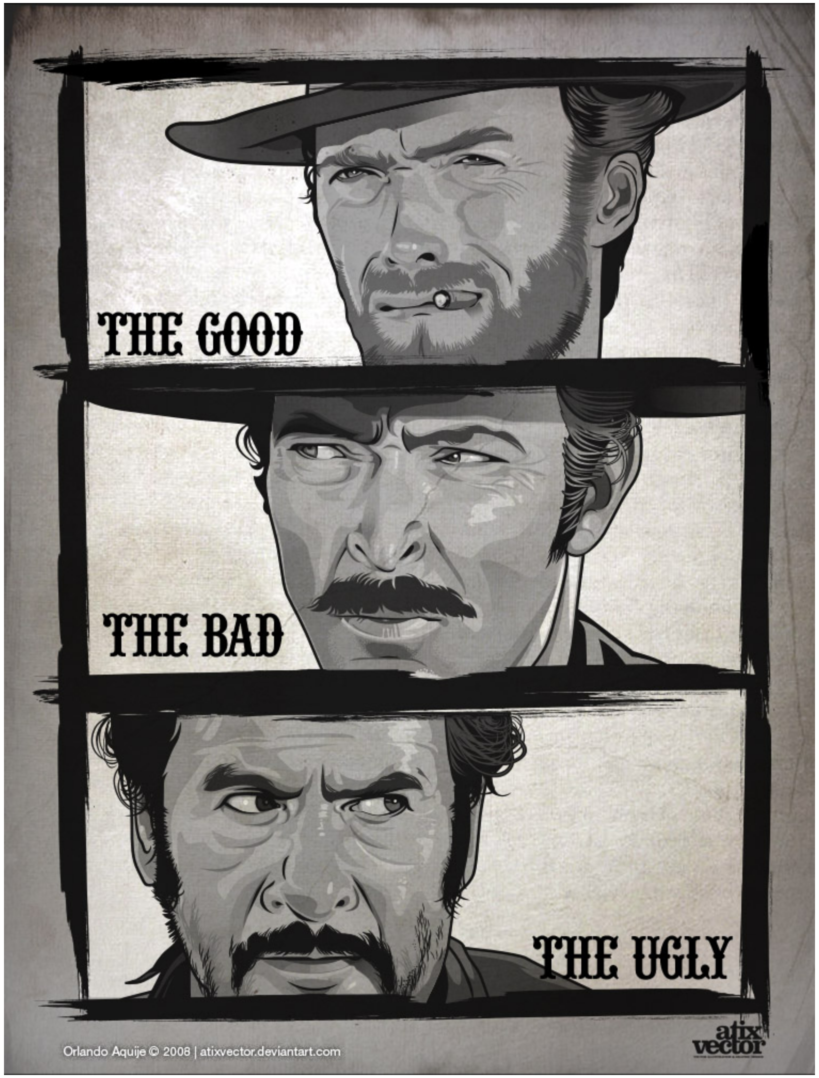
The good, the bad and the ugly

# WHO ARE WE?

- **Tobias Zillner**
- Senior IS Auditor @Cognosec in Vienna
  - Penetration Testing, Security Audits, Security Consulting
  - Breaking stuff
- Owner of a ZigBee based home automation system :D

- **Sebastian Strobl**
- Principal Auditor @Cognosec in Vienna
  - Plans and leads various types of IT audits
- Still trying to get his HD drone vision to work
- Now uses Z-Wave for home automation until we manage to break it too

# AGENDA



- Introduction
- ZigBee Security Measures
  - The good
- ZigBee Application Profiles
  - The bad
- ZigBee Implementations
  - The ugly
- Demonstration
- Summary

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# WHAT IT’S ABOUT?

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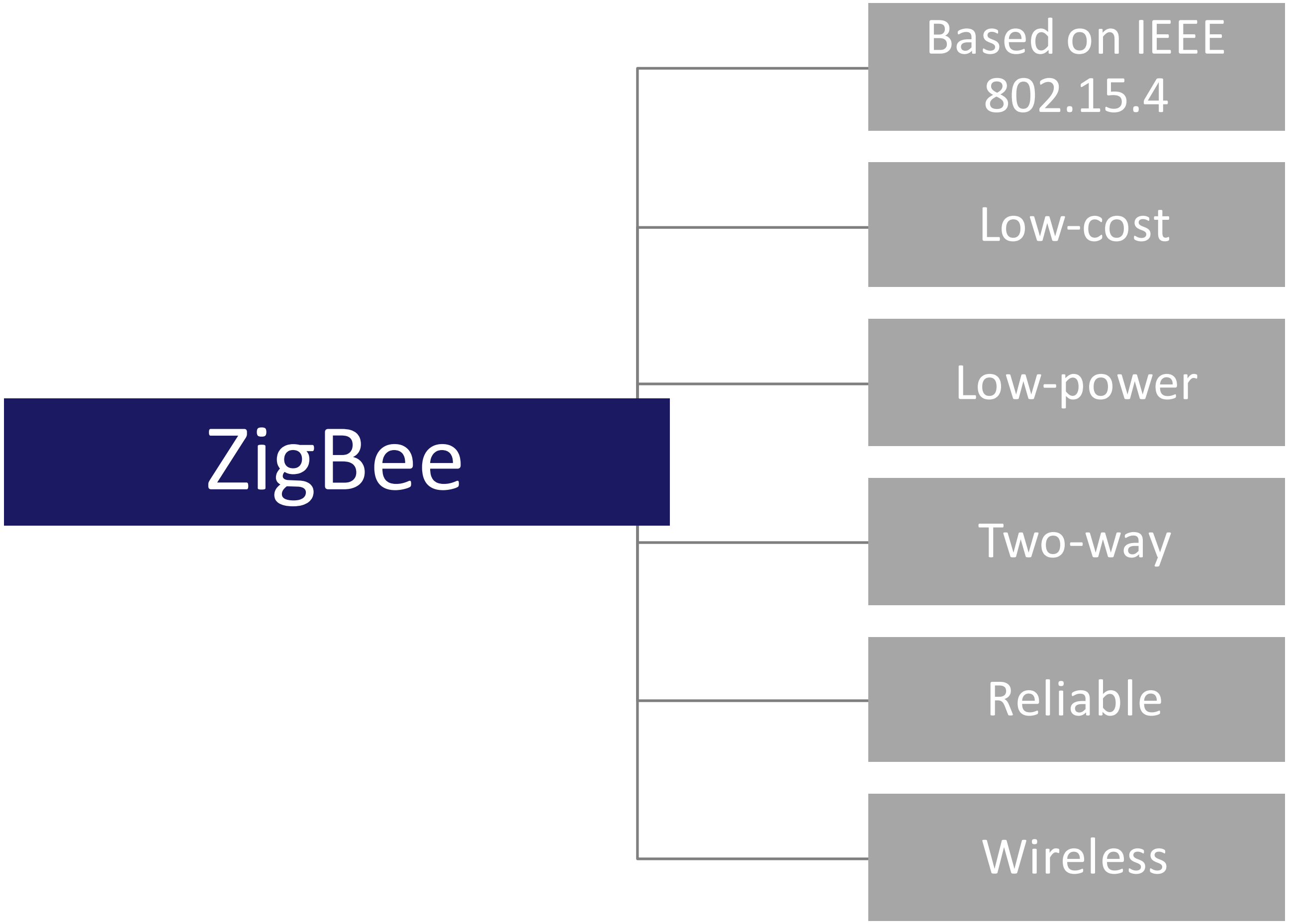
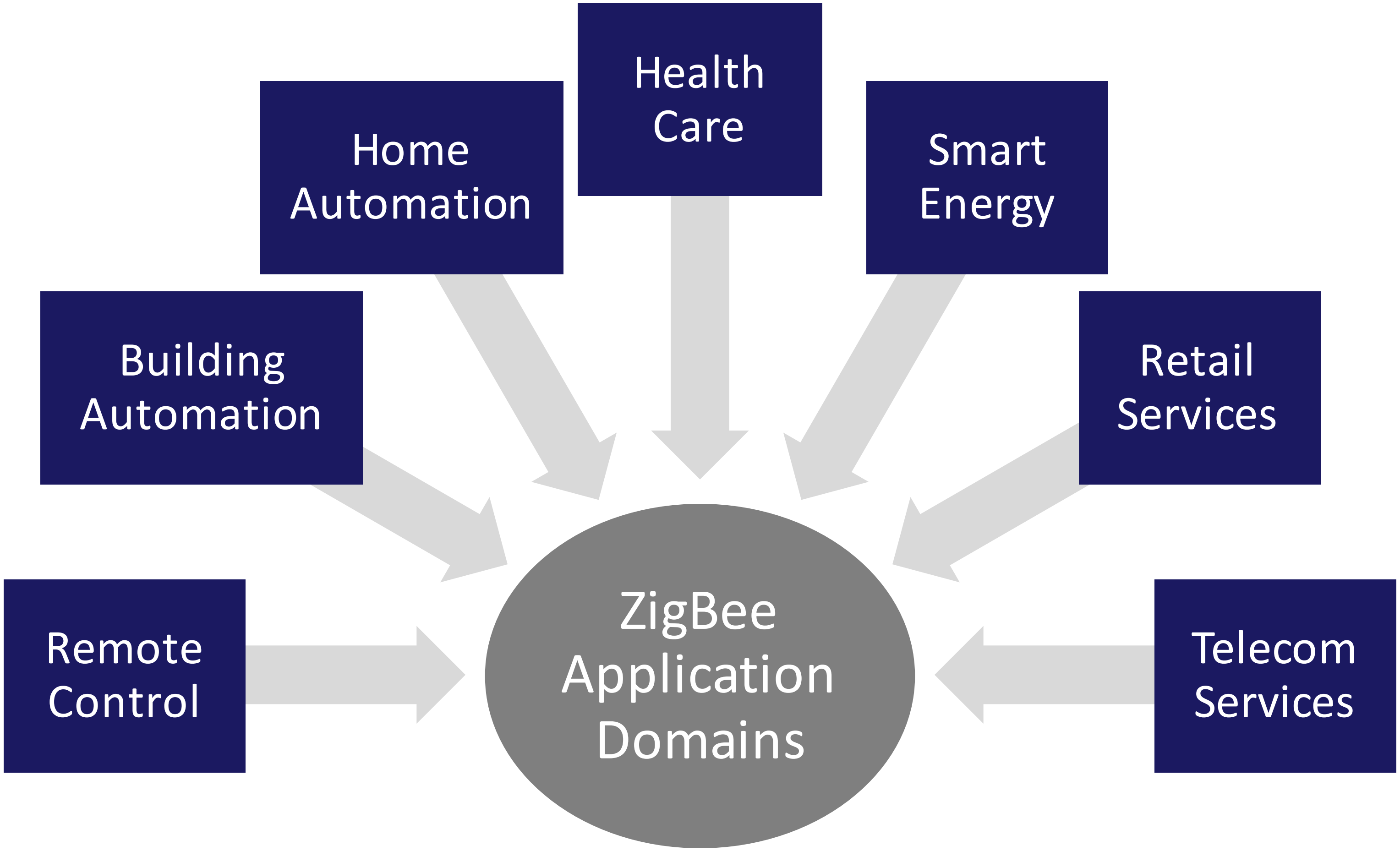
# WHAT IS ZIGBEE?



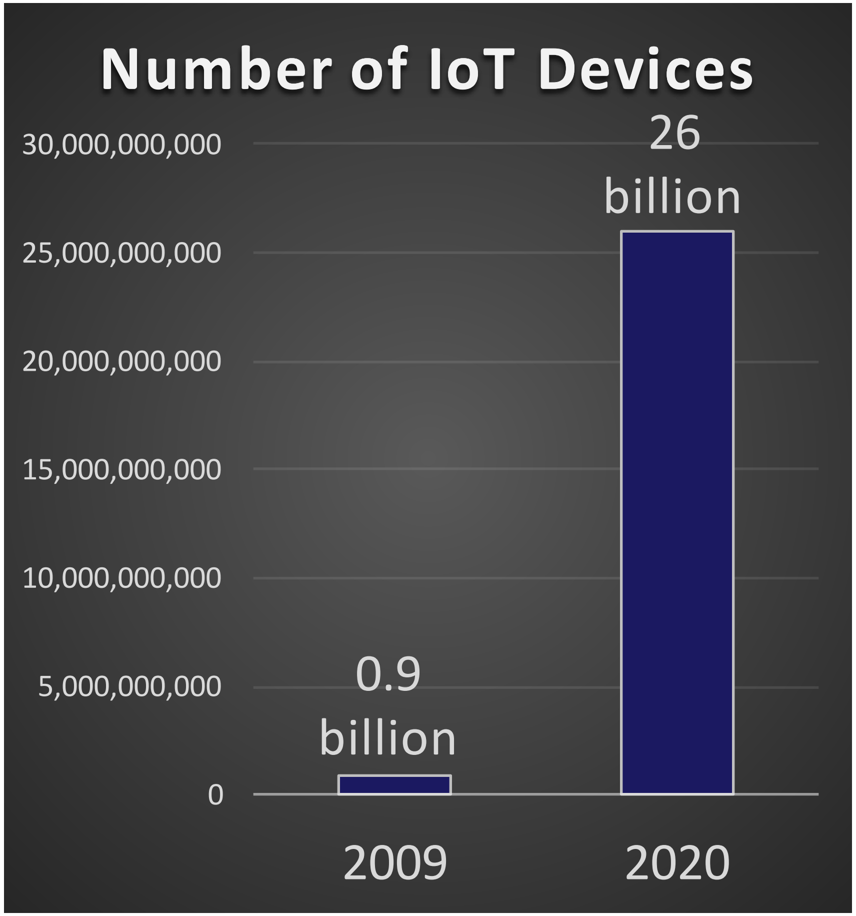
ZigBee

- Based on IEEE 802.15.4
- Low-cost
- Low-power
- Two-way
- Reliable
- Wireless

# WHERE IS IT USED?



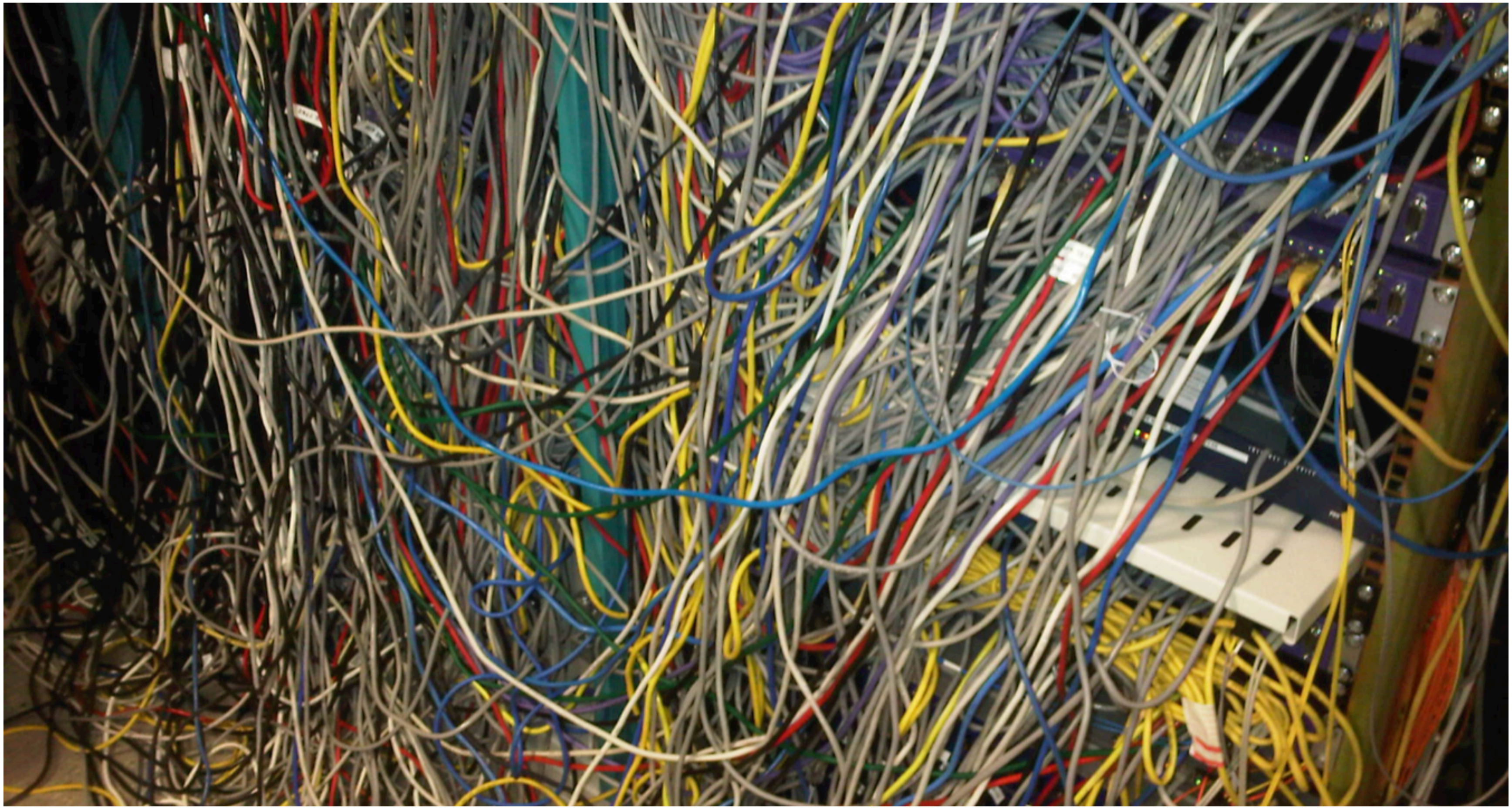
# WHY IS IT IMPORTANT?



- Trend is wireless connections
- Samsung CEO BK Yoon:
  - *“Every Samsung device will be part of IoT till 2019”* [3]
- Over 500 smart device per household in 2022 [1]

[1] http://www.gartner.com/newsroom/id/2839717
[2] http://www.gartner.com/newsroom/id/2636073
[3] http://www.heise.de/newsticker/meldung/CES-Internet-der-Dinge-komfortabel-vernetzt-2512856.html

# FUTURE OF WIRED IOT



https://hivizme.files.wordpress.com/2012/06/cable-mess.jpg

# WHY SECURITY?

- ***HOME*** automation has high privacy requirements
- Huge source of personalized data

> " Items of interest will be located, identified, monitored, and remotely controlled through technologies such as radio-frequency identification, sensor networks, tiny embedded servers, and energy harvesters - all connected to the next-generation internet[1] "

-Former CIA Director
David Petraeus

[1] http://www.wired.com/2012/03/petraeus-tv-remote/

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# ZIGBEE SECURITY MEASURES

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THE GOOD

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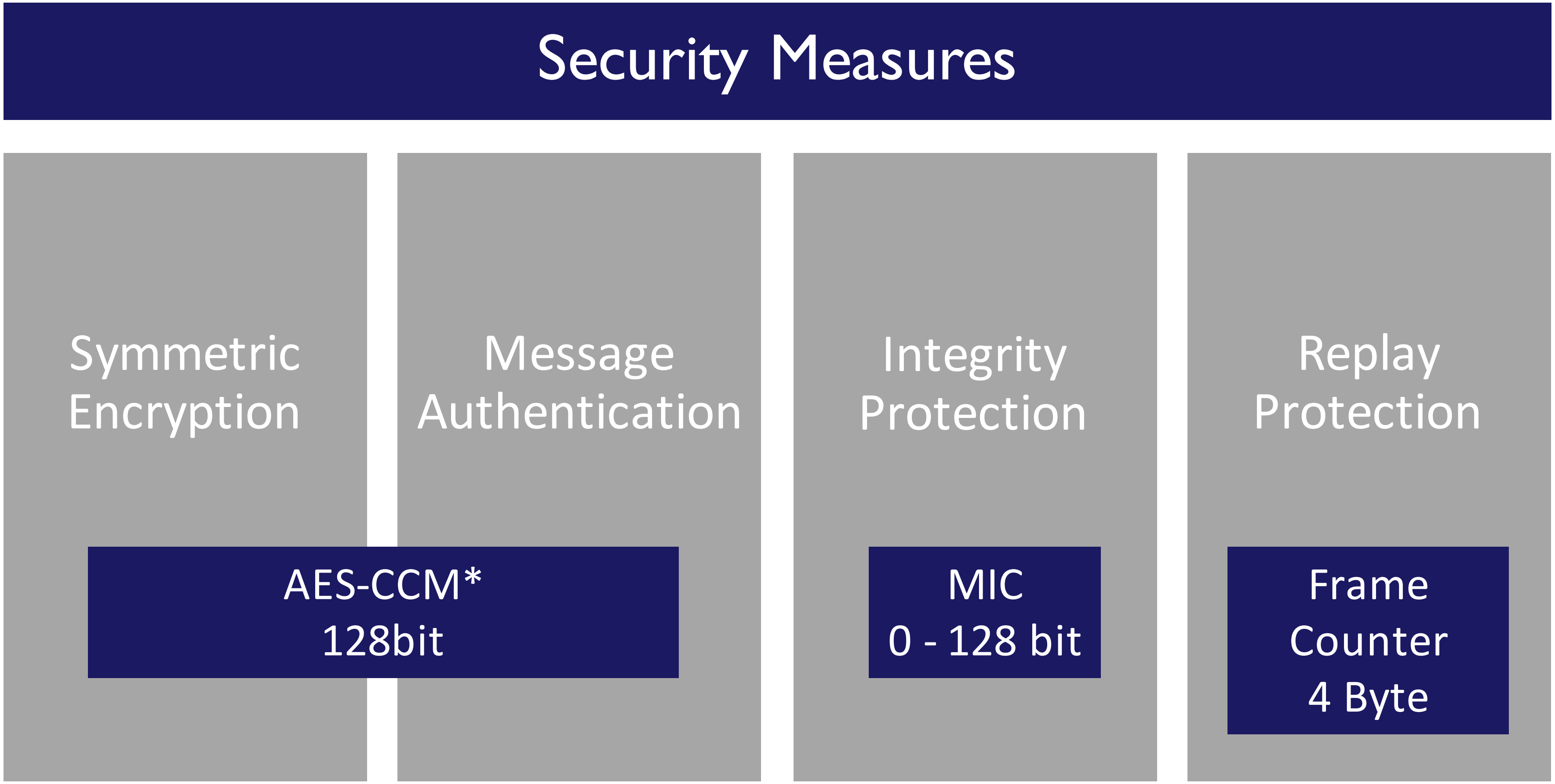
# ZIGBEE SECURITY MEASURES



## Security Measures

Symmetric Encryption

Message Authentication

Integrity Protection

Replay Protection

AES-CCM*
128bit

MIC
0 - 128 bit

Frame
Counter
4 Byte

# ZIGBEE SECURITY

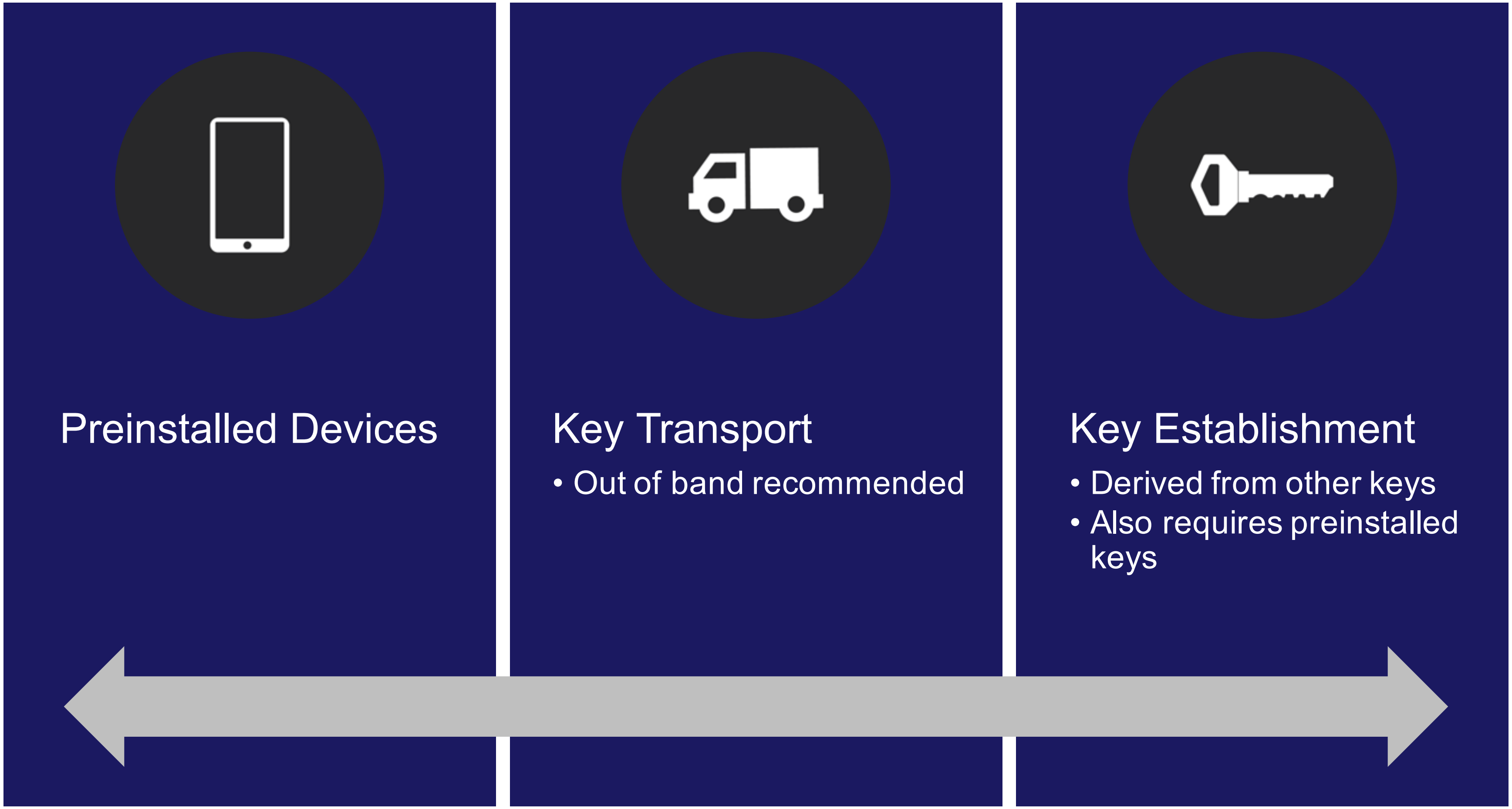
- One security level per network
- Security based on encryption keys
    - Network Key
        - Used for broadcast communication
        - Shared among all devices
    - Link Key
        - Used for secure unicast communication
        - Shared only between two devices

# SECURITY ARCHITECTURE

Trust in the security is ultimately reduces to:

- Trust in the secure **initialization** of keying material
- Trust in the secure **installation** of keying material
- Trust in the secure **processing** of keying material
- Trust in the secure **storage** of keying material

# HOW ARE KEYS EXCHANGED?



## Preinstalled Devices

## Key Transport

- Out of band recommended

## Key Establishment

- Derived from other keys
- Also requires preinstalled keys

# ZIGBEE APPLICATION PROFILES

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THE BAD

# APPLICATION PROFILES

- Define communication between devices
  - Agreements for messages
  - Message formats
  - Processing actions

- Enable applications to
  - Send commands
  - Request data
  - Process commands
  - Process requests

- Startup Attribute Sets (SAS) provide interoperability and compatibility

# HOME AUTOMATION

- Default Trust Center Link Key
  - *0x5A 0x69 0x67 0x42 0x65 0x65 0x41 0x6C 0x6C 0x69 0x61 0x6E 0x63 0x65 0x30 0x39*
  - ZigBeeAlliance09

- Use Default Link Key Join
  - *0x01(True)*
  - *This flag enables the use of default link key join as a fallback case at startup time.*

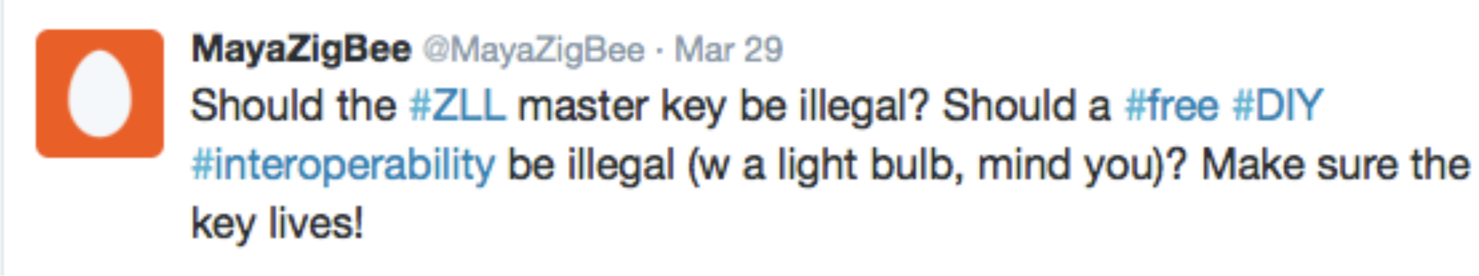
- Return to Factory Defaults
  - *In support of a return to factory default capability, HA devices shall implement a Network Leave service. Prior to execution of the NWK Leave […] the device shall ensure all operating parameters are reset to allow a reset to factory defaults.*

# LIGHT LINK

- Devices in a ZLL shall use ZigBee network layer security.
- *“The ZLL security architecture is based on using a fixed secret key, known as the ZLL key, which shall be stored in each ZLL device. All ZLL devices use the ZLL key to encrypt/decrypt the exchanged network key. “*
- *“It will be distributed only to certified manufacturers and is bound with a safekeeping contract“*

# LIGHT LINK

rt: @MayaZigBee
#DIY lover #ZLL master key 9F 55 95 F1 02 57 C8 A4 69 CB F4 2B C9 3F EE 31 #ZigBee #Philips #Hue



**MayaZigBee** @MayaZigBee · Mar 29
Should the #ZLL master key be illegal? Should a #free #DIY #interoperability be illegal (w a light bulb, mind you)? Make sure the key lives!

# LIGHT LINK

- nwkAllFresh
  - *False*
  - *Do not check frame counter*
- Trust center link key
  - *0x5a 0x69 0x67 0x42 0x65 0x65 0x41 0x6c 0x6c 0x69 0x61 0x6e 0x63 0x65 0x30 0x39*
  - *Default key for communicating with a trust center*
- Use insecure join
  - *True*
  - *Use insecure join as a fallback option.*

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# ZIGBEE IMPLEMENTATIONS

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# THE UGLY

# OFFICAL STATEMENT

- "*To avoid "bugs" that an attacker can use to his advantage, it is crucial that security be well implemented and tested. […] Security services should be implemented and tested by security experts […].*" (ZigBee Alliance 2008, p. 494)

# REQUEST KEY SERVICE

- "*The request-key service provides a secure means for a device to request the active network key, or an end-to-end application master key, from another device*" (ZigBee Alliance 2008, p. 425)

# ZBOSS

```
/**
   Remote device asked us for key.

   Application keys are not implemented.
   Send current network key.
   Not sure: send unsecured?
   What is meaning of that command??
   Maybe, idea is that we can accept "previous" nwk
   key?
   Or encrypt by it?
*/
```

# ZBOSS

```
/*
        Initiate unsecured key transfer.
        Not sure it is right, but I really have no
        ideas about request meaning of key for
        network key.
*/
```

# TESTED DEVICES

- Door Lock
- Smart Home System
- Lighting Solutions

# RESULTS

- ALL tested systems only use the default TC Link Key for securing the initial key exchange
- No link keys are used or supported
  - Complete compromise after getting network key
- No ZigBee security configuration possibilities available
- No key rotation applied
  - Test period of 11 month

# RESULTS

- Device reset often difficult
  - Removal of key material not guaranteed
  - One device does not support reset at all
- Light bulbs do not require physical interaction for pairing
- Workarounds like reduced transmission power are used to prevent pairing problems
  - Devices have to be in very close proximity for pairing

DEMONSTRATION

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SecBee

# SecBee

- ZigBee security testing tool
- Target audience
  - Security testers
  - Developers

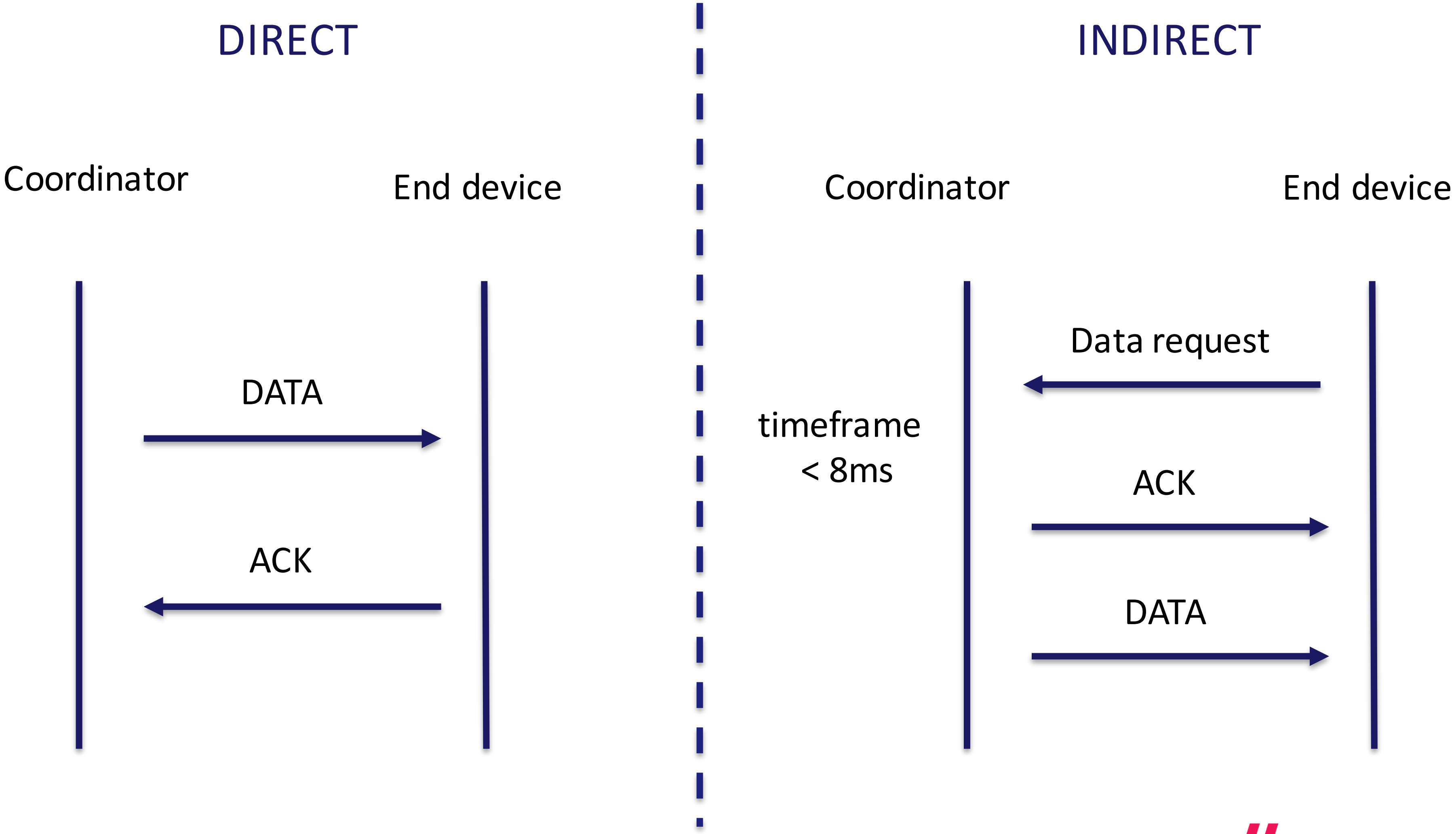
Raspbee

USRP B210

- Based on *scapy-radio, µracoli* and *killerbee*
- Provides features for testing of security services as well as weak security configuration and implementation
  - Support of encrypted communication
  - Command injection
  - Scan for weak key transport
  - Reset to factory
  - Join to network
  - Test security services

https://github.com/zu1na/SecBee

# DATA TRANSFER



# DEMONSTRATION

# -

# KEY EXTRACTION

# NETWORK KEY SNIFFING

Fallback key exchange insecure

Most vendors only implement fallback solution

Same security level as plaintext exchange

# VENDOR COMMENT

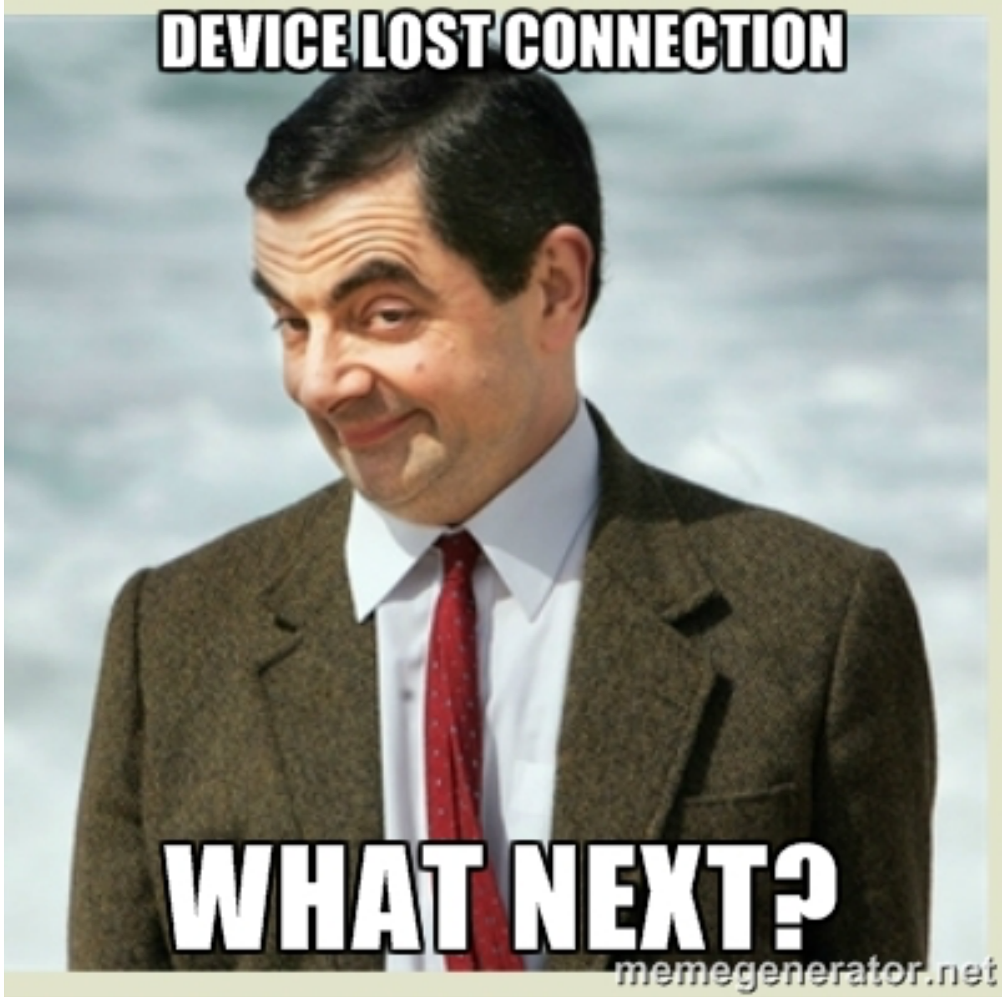
# NETWORK KEY SNIFFING

So, the

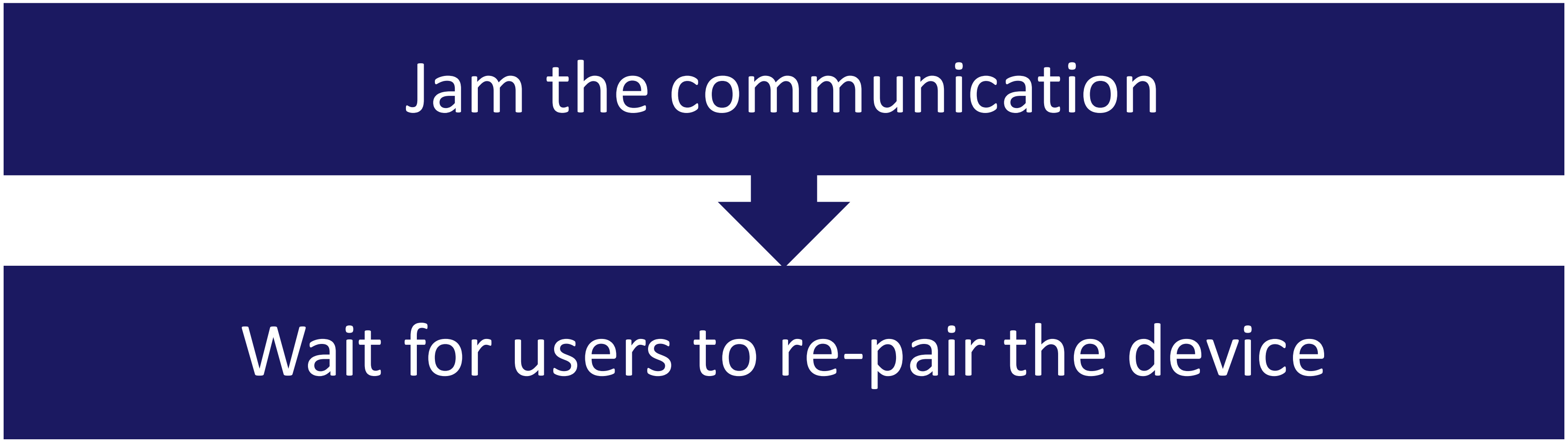
1. Timeframe is limited
2. Proximity is necessary
3. Key extraction works only during pairing

… what would an attacker do?

# Typical End-User



# NETWORK KEY SNIFFING



Jam the communication

Wait for users to re-pair the device

It is not only about technology :D

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DEMONSTRATION

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COMMAND INJECTION

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# DEMONSTRATION

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# DEVICE HIJACKING

# DEVICE HIJACKING

Devices are paired and working

1. Identify the target device

2. Reset to factory default settings

1. Join the target device to our network

# DEVICE HIJACKING

⚠ No physical access is required

⚠ No knowledge of the secret key is needed

⚠ Usability overrules security

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# SUMMARY

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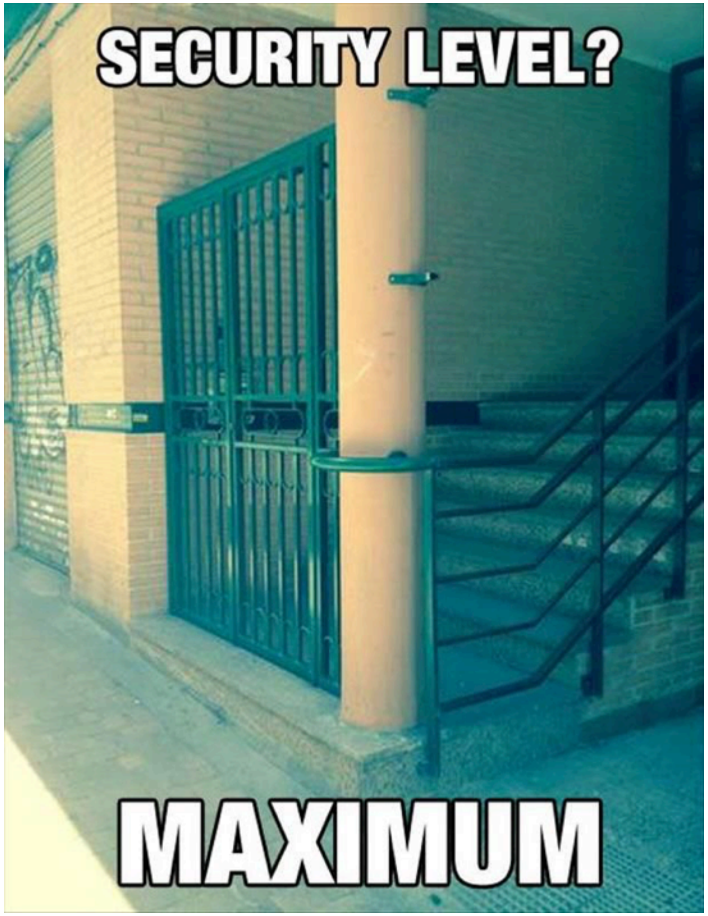
# SUMMARY

- Security measures provided are good
- Requirements due to interoperability weaken the security level drastically
- Vendors only implement the absolute minimum to be compliant
- Usability overrules security



# BLACK HAT SOUND BYTES

- Proper implementation of security measures is crucial - Compliance is not Security
- Learn from history and do not rely on "Security by Obscurity"
- There is a world beside TCP/IP

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# THANK YOU!

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TIME FOR QUESTIONS

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LET’S TALK ABOUT IT

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